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Multi-Objective Optimization of System Capability Satisficing in Defense Acquisition

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Stevens Institute of Technology

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14. ABSTRACT

Under support from the Acquisition Research Program and government/industry partnerships, previous research has successfully developed, tested, and implemented a system maturity measure (i.e., a system readiness level [SRL]); supporting optimization models; and an enhanced SRL hierarchy for multi-function, multi-capability (MFMC) systems. The later developments are predicated on what has become the accustomed challenge for managers and engineers to properly assess systems? development and acquisition to ensure the achievement of critical capabilities and functions while deciding among multiple technologies with similar functionalities but different maturity levels and limited resources. Building on these developments, the proposed research responds to the question: How can we efficiently and effectively allocate available resources to ensure the maturity achievement of critical functions and capabilities in a MFMC system when facing competing technology alternatives? As an answer, we propose the development of multi-objective optimization models and solution approaches that can be used to evaluate systems? development maturity, to track progress, to identify component criticality, and to form corresponding strategies for understanding trade-offs in technology and integration options. Further, this effort summarizes and document the previous and proposed research in cooperation with industry and government partners to produce a comprehensive guidebook for public distribution on the proper application of this research in methods, processes, and tools (MPT) for defense acquisition.

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Preface & Acknowledgements

Welcome to our Ninth Annual Acquisition Research Symposium! This event is the highlight of the year for the Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) because it showcases the findings of recently completed research projects—and that research activity has been prolific! Since the ARP's founding in 2003, over 800 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 60 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a "broker" to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and hope this symposium will spark even more participation.

We encourage you to be active participants at the symposium. Indeed, active participation has been the hallmark of previous symposia. We purposely limit attendance to 350 people to encourage just that. In addition, this forum is unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. Seldom will you get the opportunity to interact with so many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. In the words of one senior government official, "I would not miss this symposium for the world as it is the best forum I've found for catching up on acquisition issues and learning from the great presenters."

We expect affordability to be a major focus at this year's event. It is a central tenet of the DoD's Better Buying Power initiatives, and budget projections indicate it will continue to be important as the nation works its way out of the recession. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you're a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

- Office of the Under Secretary of Defense (Acquisition, Technology, & Logistics)
- Director, Acquisition Career Management, ASN (RD&A)
- Program Executive Officer, SHIPS
- Commander, Naval Sea Systems Command
- Program Executive Officer, Integrated Warfare Systems
- Army Contracting Command, U.S. Army Materiel Command
- Office of the Assistant Secretary of the Air Force (Acquisition)

- Office of the Assistant Secretary of the Army (Acquisition, Logistics, & Technology)
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- Director, Office of Acquisition Resources and Analysis (ARA)
- Deputy Assistant Secretary of the Navy, Acquisition & Procurement
- Director of Open Architecture, DASN (RDT&E)
- Program Executive Officer, Littoral Combat Ships

We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this symposium.

James B. Greene Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

Panel 2. Systems Engineering for Complex Systems Acquisition

Wednesday, May 16, 2012	
11:15 a.m. – 12:45 p.m.	**Chair: Joseph L. Yakovac Jr., LTG, USA, (Ret.),** Naval Postgraduate School; former Military Deputy to the Assistant Secretary of the Army for Acquisition, Logistics and Technology ***System Definition-Enabled Acquisition (SDEA)—A Concept for Defining Requirements for Applying Model-Based Systems Engineering (MBSE) to the Acquisition of DoD Complex Systems*** Paul Montgomery, Ron Carlson, and John Quartuccio *Naval Postgraduate School* ***Development and Extension of a Deterministic System of Systems Performance Prediction Methodology for an Acknowledged System of Systems*** Richard Volkert and Carly Jackson, *SSC-Pacific* Jerrell Stracener and Junfang Yu, *Southern Methodist University* ***Multi-Objective Optimization of System Capability Satisficing in Defense Acquisition*** Brian Sauser and Jose E. Ramirez-Marquez *Stevens Institute of Technology*

Joseph L. Yakovac Jr.—Lt. Gen. Yakovac retired from the United States Army in 2007, concluding 30 years of military service. His last assignment was as director of the Army Acquisition Corps and military deputy to the Assistant Secretary of Defense for Acquisition, Logistics, and Technology. In those roles, Lt. Gen. Yakovac managed a dedicated team of military and civilian acquisition experts to make sure America's soldiers received state-of-the-art critical systems and support across a full spectrum of Army operations. He also provided critical military insight to the Department of Defense senior civilian leadership on acquisition management, technological infrastructure development, and systems management.

Previously, Lt. Gen. Yakovac worked in systems acquisition, U.S. Army Tank-Automotive Command (TACOM), and in systems management and horizontal technology integration for the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology. He has also served as executive officer and branch chief for the Bradley Fighting Vehicle and as a brigade operations officer and battalion executive officer, U.S. Army Europe and U.S. Army Tank-Automotive Command (TACOM).

Lt. Gen. Yakovac was commissioned in the infantry upon his graduation from the U.S. Military Academy at West Point. He served as a platoon leader, executive officer, and company commander in mechanized infantry units. He earned a Master of Science in mechanical engineering from the University of Colorado at Boulder before returning to West Point as an assistant professor.
Lt. Gen. Yakovac is a graduate of the Armor Officer Advanced Course, the Army Command and General Staff College, the Defense Systems Management College, and the Industrial College of the Armed Forces. He has earned the Expert Infantry Badge, the Ranger Tab, the Parachutist Badge, and for his service has received the Distinguished Service Medal, the Legion of Merit three times and the Army Meritorious Service Medal seven times.

Multi-Objective Optimization of System Capability Satisficing in Defense Acquisition

Brian Sauser—Sauser received his BS in agriculture development from Texas A&M University; his MS in bioresource engineering from Rutgers, The State University of New Jersey; and his PhD in technology management from the Stevens Institute of Technology. He is currently an associate professor at Stevens Institute of Technology in the School of Systems and Enterprises. [bsauser@stevens.edu]

Jose E. Ramirez-Marquez—Ramirez-Marquez received his BS in actuarial science from Universidad Nacional Autónoma de México, his MS in statistics, and his MS and PhD in industrial and systems engineering from Rutgers, The State University of New Jersey. He is currently an assistant professor at Stevens Institute of Technology in the School of Systems and Enterprises. [jmarquez@stevens.edu]

Abstract

Under support from the Acquisition Research Program and government/industry partnerships, previous research has successfully developed, tested, and implemented a system maturity measure (i.e., a system readiness level [SRL]); supporting optimization models; and an enhanced SRL hierarchy for multi-function, multi-capability (MFMC) systems. The later developments are predicated on what has become the accustomed challenge for managers and engineers to properly assess systems' development and acquisition to ensure the achievement of critical capabilities and functions while deciding among multiple technologies with similar functionalities but different maturity levels and limited resources. Building on these developments, the proposed research responds to the question: How can we efficiently and effectively allocate available resources to ensure the maturity achievement of critical functions and capabilities in a MFMC system when facing competing technology alternatives? As an answer, we propose the development of multi-objective optimization models and solution approaches that can be used to evaluate systems' development maturity, to track progress, to identify component criticality, and to form corresponding strategies for understanding trade-offs in technology and integration options. Further, this effort summarizes and document the previous and proposed research in cooperation with industry and government partners to produce a comprehensive guidebook for public distribution on the proper application of this research in methods, processes, and tools (MPT) for defense acquisition.

Executive Summary

Through support from the Naval Postgraduate School (NPS) and government/industry partnerships, the Systems Development and Maturity Laboratory (SysDML) at Stevens Institute of Technology has

a) developed a methodology for determining a system's development/acquisition maturity (i.e., system readiness level [SRL]; Sauser, Ramirez-Marquez, Magnaye, & Tan, 2008a, 2008b);
b) formulated two optimization models for allocating resources so as to optimize cost, or schedule, or maturity performance (i.e., SRL_{max} and $SCOD_{min}$; Magnaye, Sauser, & Ramirez-Marquez, 2010; Ramirez-Marquez & Sauser, 2009);
c) defined a methodology that combines items (a) and (b) into an approach called systems earned readiness management (SERM; Magnaye, 2010; Magnaye, Sauser, & Ramirez-Marquez, 2009);
d) developed models to determine which components (understood as the technologies that are integrations off of which the system is built) are

sufficient, critical, or important to achieve a level of system maturity for the intended functionalities and capabilities that can satisfy warfighter's needs (Tan, Sauser, & Ramirez-Marquez, 2011b; Tan et al., 2010); and

e) proposed an enhanced SRL hierarchy that enables maturity assessment at capability, function, and system levels; and incorporated an analysis of alternatives (AoA, or trade-off) for technology and integration component adoption, which impacts the system maturity, functionality, and capability (Tan et al., 2011a; Tan, et al., 2011b).

While these efforts are necessary and relevant to the understanding of systems maturity and alternatives comparison and prioritization, its application is limited in an acquisition situation where in the procurement of a complex system there are many technology alternatives with the same functionality but different maturity statuses or different cost requests for further maturation. Therefore, this research intends to build on the current AoA research to propose the employment of multi-objective (MO) optimization models for systems of multiple functions and multiple capabilities (MFMC).

Contrary to the single-objective optimization models developed in previous research, this proposed effort will develop and solve the MO problem and provide a range of solutions to assist managers with flexibility in the planning of system acquisition and further system maturation. Thus, this research will address a fundamental question: *How can we efficiently and effectively allocate available resources to ensure the maturity achievement of critical functions and capabilities in a MFMC system when facing competing technology alternatives?* As a summary of the efforts of the SysDML, Figure 1 summarizes previous research, how it relates to the proposed research, and a guidebook under development by the SysDML that explains the theory and application of this research.

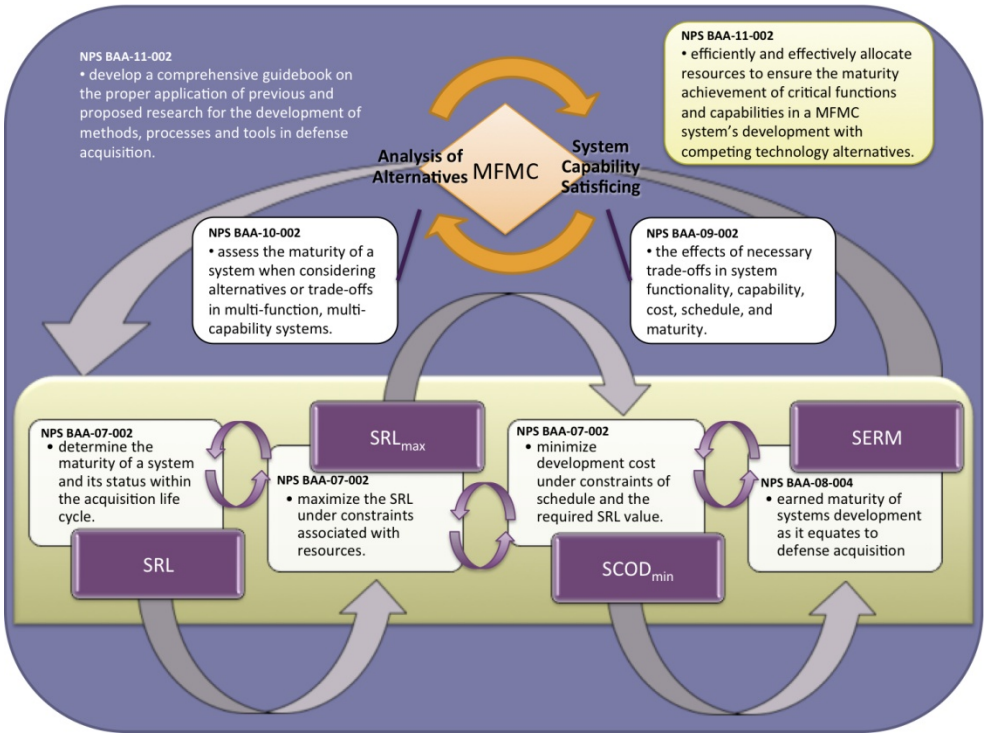

Figure 1. Evolutionary Development Plan

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SYSTEMS Development & Maturity Laboratory

Analyzing Component Importance in Multi-Function Multi-Capability Systems Developmental Maturity Assessment

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Human Maturity

- Emotional
- Physical
- Intellectual

System Maturity

- Functional
- Physical
- Logical

Emotional-Functional

Indicates how a system responds to the circumstances or environment in an appropriate and adaptive manner.

Physical-Physical

This response is designed (in some instances learned) and not determined by the system's age.

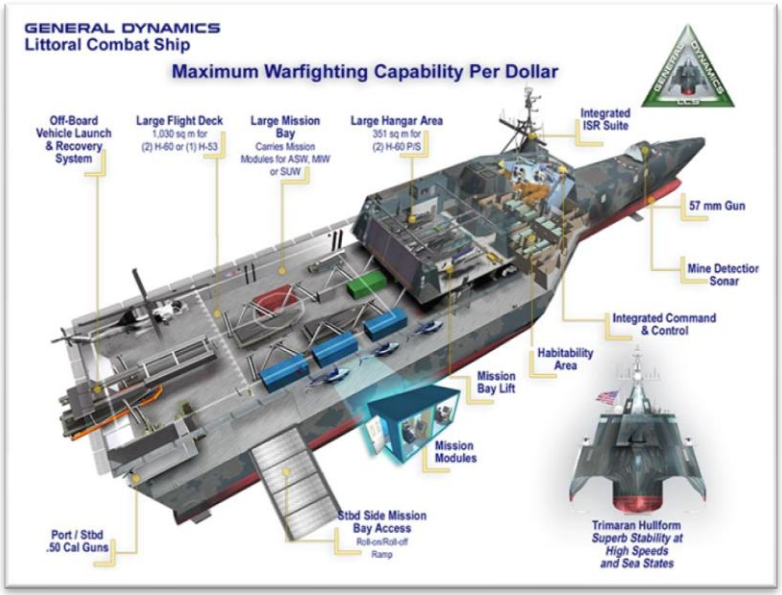
Intellectual-Logical

Encompasses being aware of the correct time and place to deploy and knowing when to operate appropriately according to the situation

http://www.talash.com/online-gardening-utilities-store-india

www.microsoft.com

http://dailymobile.se/2010/07/28/iphone-4-vs-iphone-2g-3g-3gs-speed-comparison/



http://www.defenseindustrydaily.com/the-usas-new-littoral-combat-ships-updated-01343/

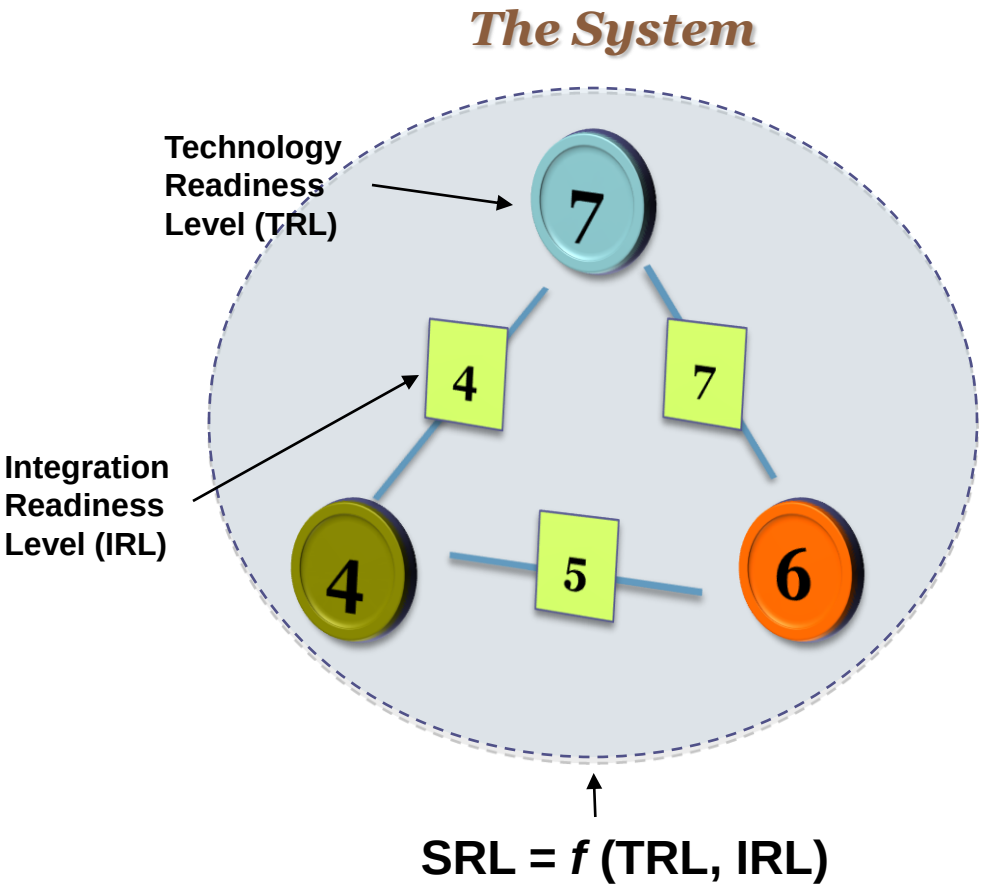
iPhone Evolution

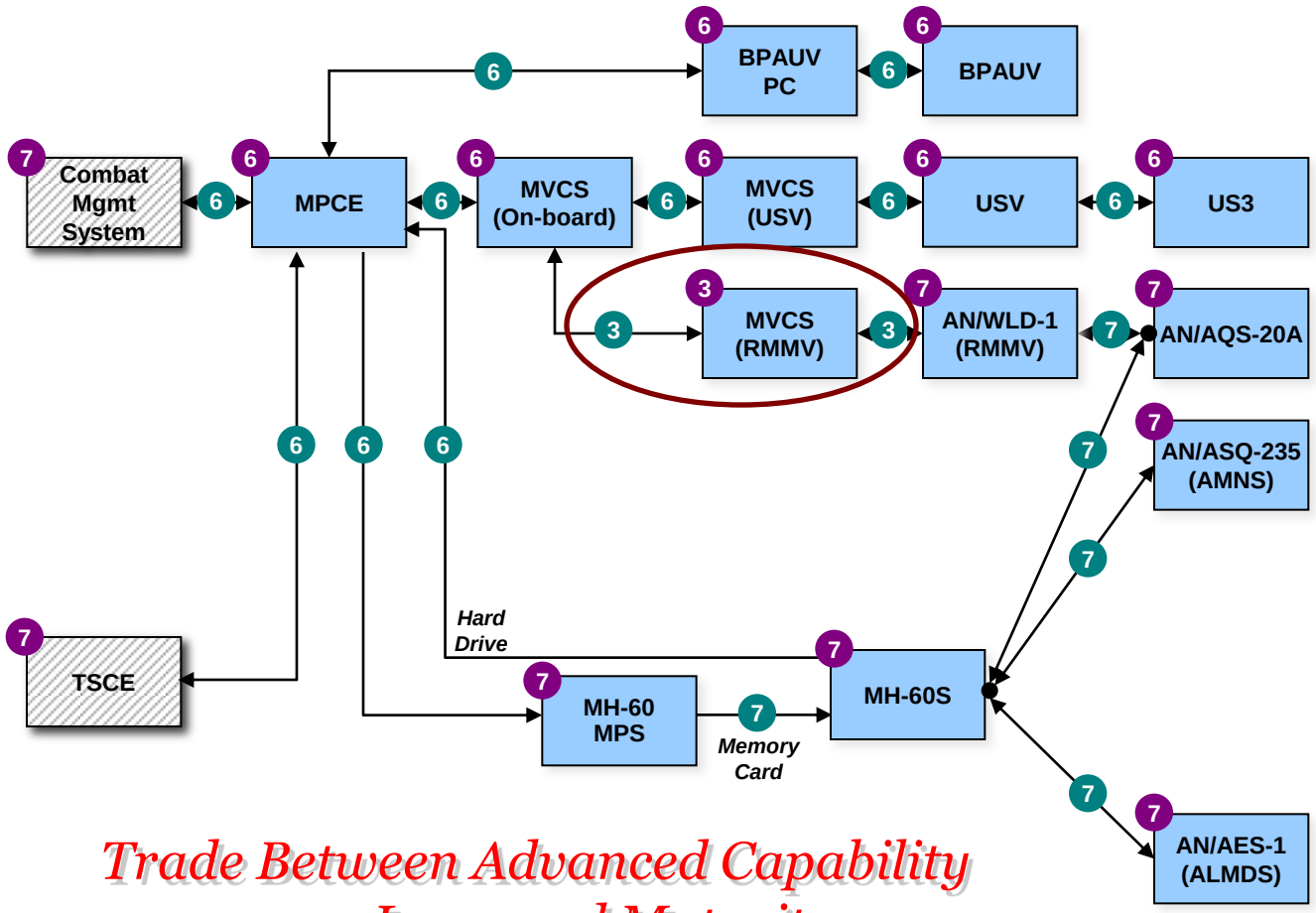
Launch Time	2007, Jun	2008, Jul	2009, Jun	2010, Jun	2011, Oct
Generation	2G 	3G 	3GS 	4G 	4GS 
New Features (not exhaustive)		• 3G connectivity • GPS	• Video recording • Voice control • Nike+ support	• Face time • Retina Display • Front and back cameras	• Siri • iCloud • Video stablization • Face detection

Systems Evolution and Lifecycle Management

Value Proposition:

- To provide a systemic view of development maturity with opportunities to drill down to element-level contributions
- To allows managers to evaluate system development to take proactive measures
- To create highly adaptive methods, processes, and tools to use on a wide array of system engineering development efforts





	MP SRL	MP SRL w/o Sea Frame
MP 1	0.60	0.57

LEGEND

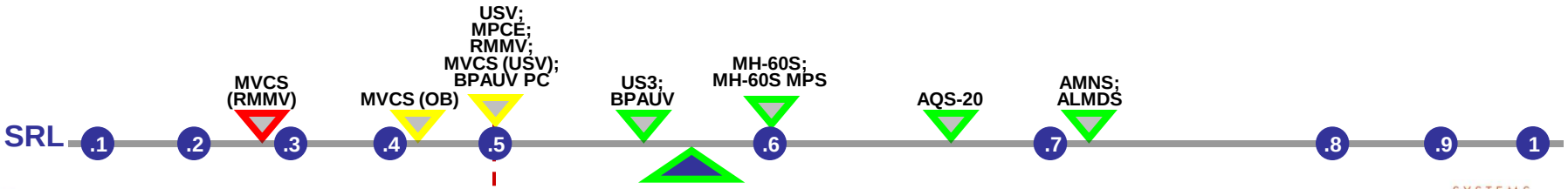
- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- Technology Readiness Level
- Integration Maturity Level
- System Readiness Level Demarcation
- Scheduled Position

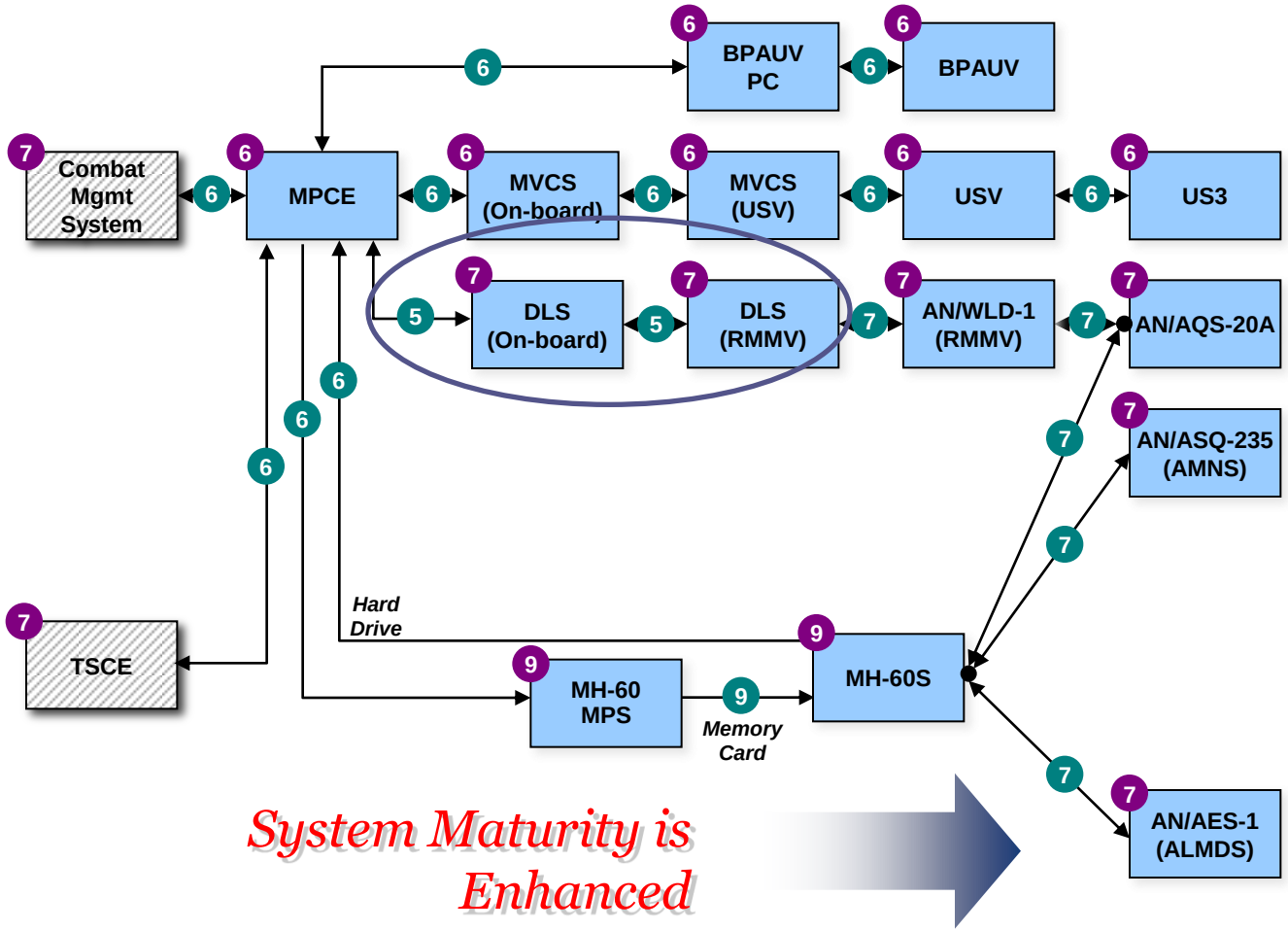
Risk to Cost and/or Schedule

Low Medium High

All Data is Notional

Trade Between Advanced Capability or Increased Maturity





	MP SRL	MP SRL w/o Sea Frame
MP 1	0.64	0.67

LEGEND

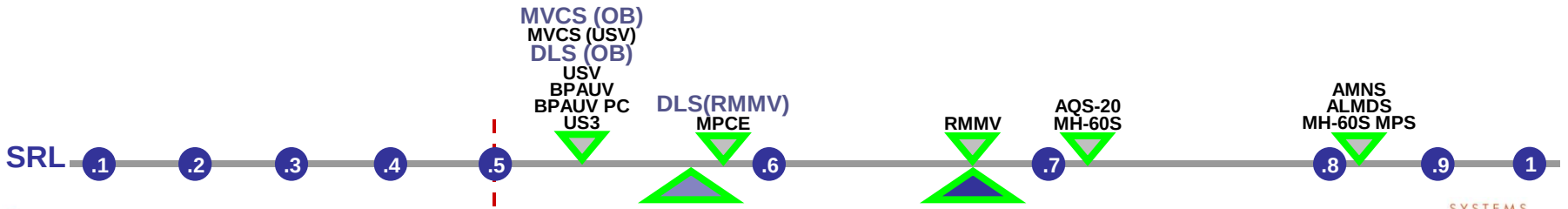
- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- Technology Readiness Level
- Integration Maturity Level
- System Readiness Level Demarcation
- Scheduled Position

Risk to Cost and/or Schedule

Low Medium High

All Data is Notional

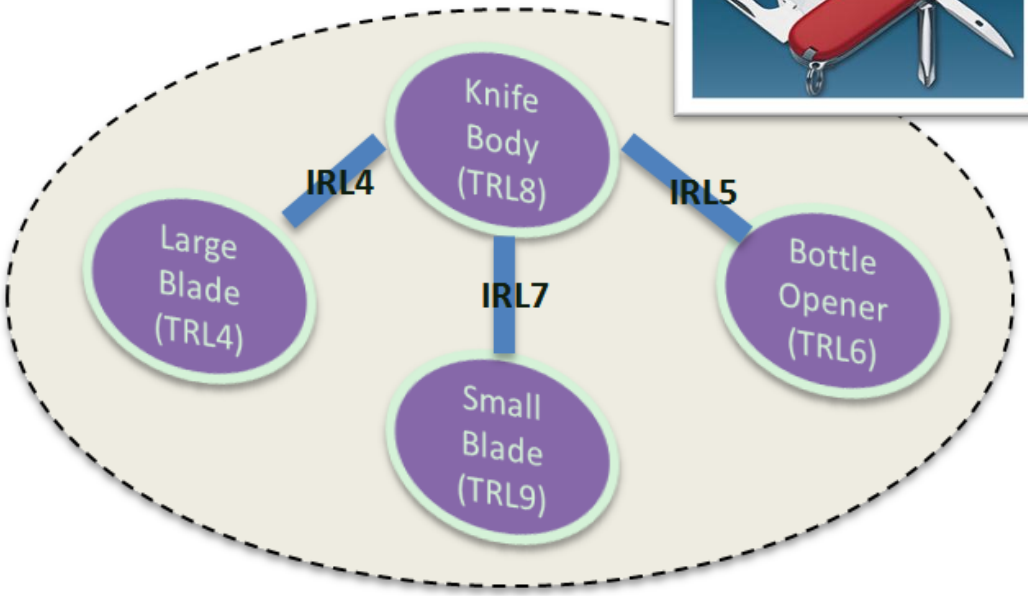
System Maturity is Enhanced

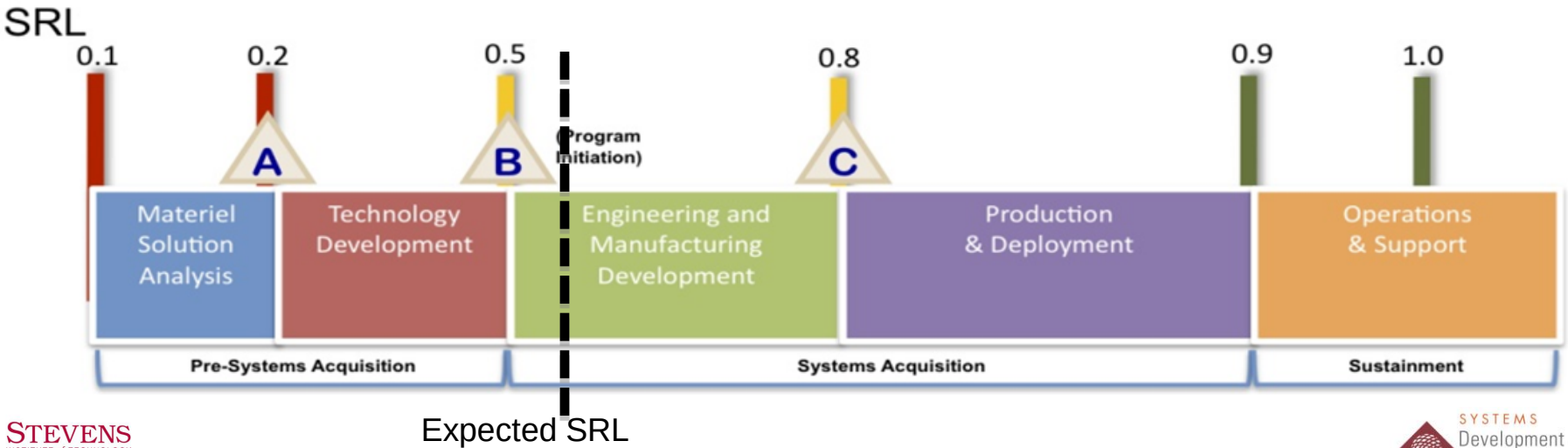


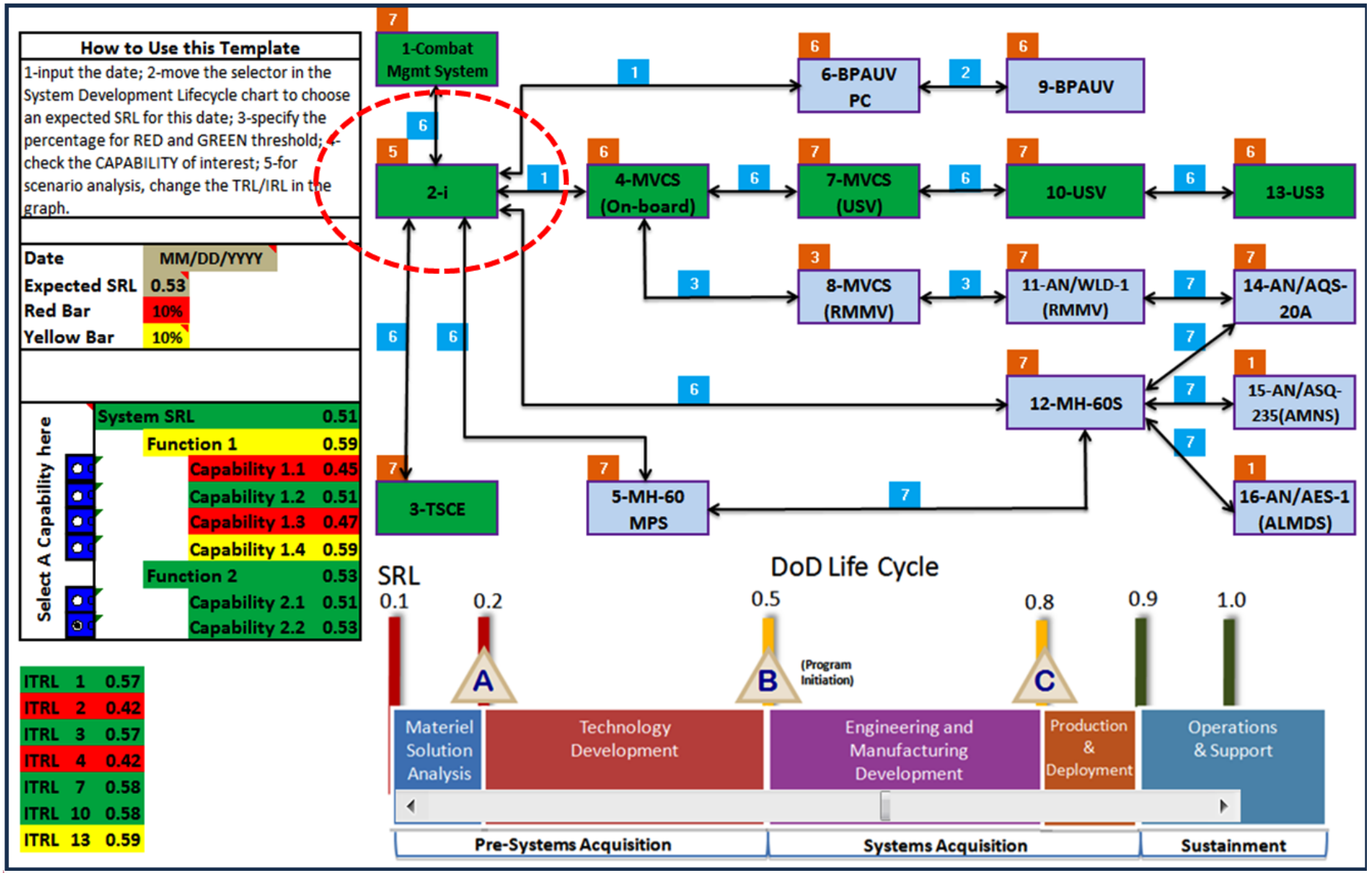
Example provided by Northrop Grumman in support of the US Navy PMS 420 Program

Multifunction Multicapability System Maturity Assessment

Date	**MM/DD/YYYY**
Expected SRL	**0.55**
System SRL	0.64







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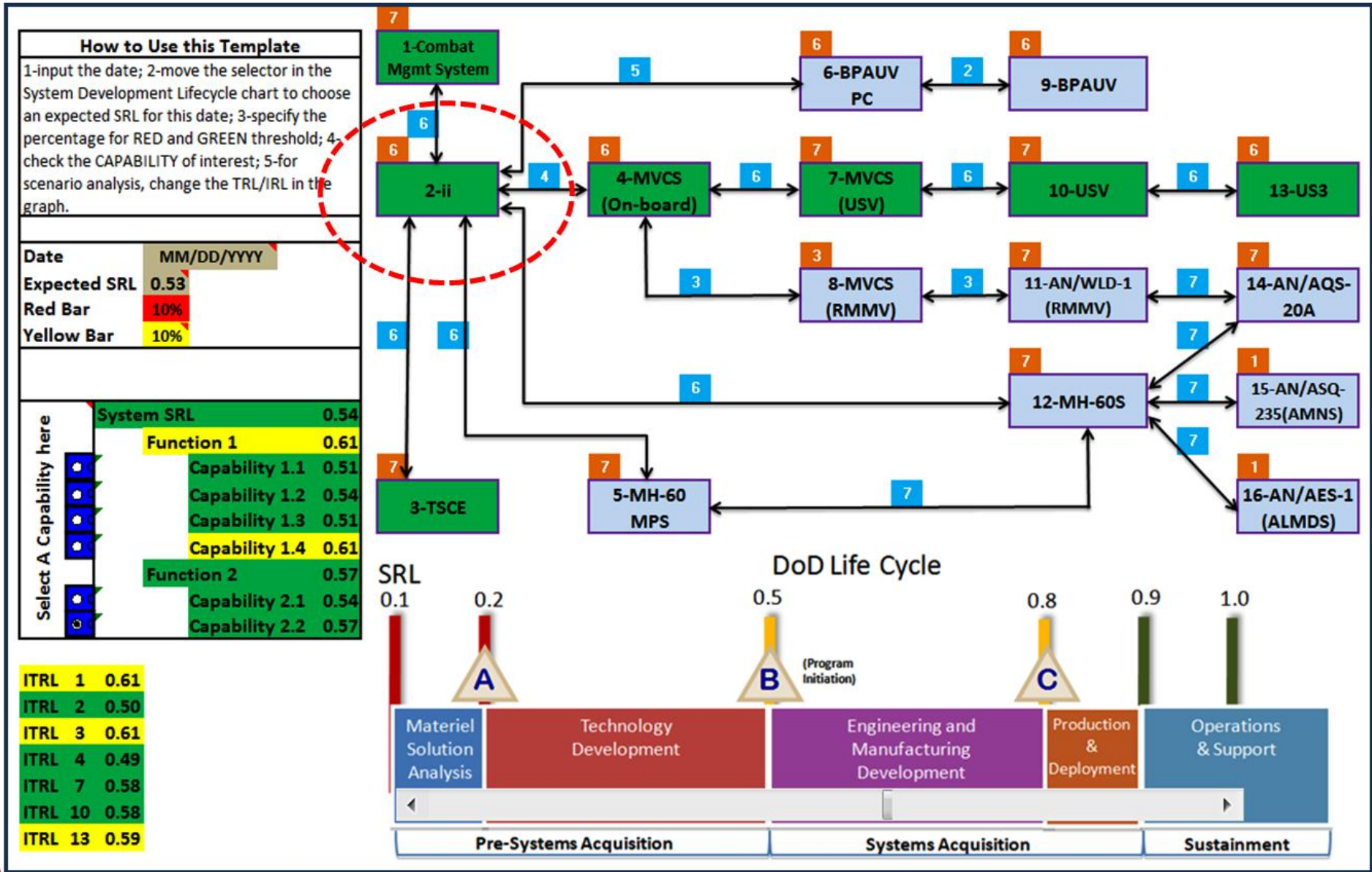

All Data is Notional

This is RESEARCH…

- *Component importance is significantly dependent on interest*: component importance should be situation-dependent
- *Discernibility in components importance determination*: difference between important components is very small, largely due to the inconsistency of estimates across all technologies
- *Technologies that have more integration rank relatively higher than those having less integration when all other factors are the same:* With out a proper weighting of component importance, intergration will drive risk
- *Maturity of one system is not the same as maturity for another system*: SRL for one system cannot be compared to the SRL of another system unless they are the same system.